US and Global Water and Energy Budget Studies: A contribution to CEOP

Progress Report for: 03/01/2004 - 02/28/2005

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Introduction

The World Climate Research Program (WCRP) is developing a Coordinated Enhanced Observing Period (CEOP), which has started and will run for the next few years. As part of CEOP, there are planned to be several global reference sites that provide a number of in situ observations of water and energy budget study (WEBS) variables. Processed satellite data (geophysical variables) will also eventually be available at these sites. Output from numerical weather prediction models are also potentially available but like the in situ and satellite data needs to be developed. In addition, NWP centers have been requested to archive a more complete synoptic gridded output set and there may eventually be corresponding gridded satellite data. Developing the hydroclimatological output from these data sets has required a special effort.

Project Goal

Our goal is to understand what components of the global water and energy cycles can be accurately measured, simulated, and predicted at regional and global scales. In particular, we hope to isolate strengths and weaknesses of our Experimental Climate Prediction Center (ECPC) global and regional models description of the diurnal cycle.

Method

ECPC model output data sets (gridded and MOLTS) now being provided to the international model output archive include: (1) NCEP/DOE Global Reanalysis II (RII; Kanamitsu et al. 2002b; L28T62 grid), and (2) NCEP's new seasonal forecast model (SFM; Kanamitsu et al. 2002a; L28T62) used in place of the RII model as part of an upgraded reanalysis (RII is an upgraded reanalysis of the original NCEP/NCAR RI). The SFM includes a number of improved parameterizations and is thus expected to provide a somewhat more realistic analysis than RII (or RI), although this still needs to be assessed. NCEP by contrast, which besides DAO and ECPC form the 3 major US modeling contributions to CEOP, is providing data from their latest forecast system as well as the original NCEP/NCAR reanalysis (RI). Again, similar output is being provided by a number of other international NWP centers. Besides the standard analysis variables available every 6 hours, 6 hour forecasts initialized from either an RII or SFM reanalysis, are made every 6 hours, and once a day, at 1200 UTC, a 36 hour forecast is made, again with both the RII and SFM models. The forecast output is available every 3 hours.

We have made a special effort to provide all of the CEOP/WESP requested variables and processes (Roads et al. 2003d) for the entire CEOP period (7/1/2001-12/31/2004). This output includes top of atmosphere, integrated and vertically varying atmospheric and surface water and energy-cycle processes and variables. It should be noted that gridded

output is developed first and archived locally, and then MOLTS (41 CEOP sites) are extracted from the gridded data. Depending upon outside requests, additional sites could be extracted later from the gridded output, which is also stored locally.

In addition to the global analysis/forecast output, we are also running the Regional Spectral Model (RSM), which is a regional counterpart to the SFM (similar physics), over all of the GEWEX Continental-Scale Experiments (CSEs) for the entire CEOP period at 50 km resolution. The lateral boundary conditions for the RSM come from the global RII. The RSM output is being stored locally but could also be made available to interested researchers. The RSM output is also being provided to the Inter-CSE Transferability Study (ICTS) being led by Burkhardt Rockel of Germany, which will focus on a regional model simulation ensemble over 7 regional domains. The continuous RSM simulations begin Jul. 1, 1999 in order to make sure the RSM land surface has equilibrated by the time we begin our analysis of the CEOP Jul. 1, 2001-Dec. 31, 2004 time period. Defining appropriate model domains, characteristics such as orography at the boundaries of the model domain and inclusion of the characteristic atmospheric processes have to be taken into account and will eventually require additional assessments from other CSE representatives. Techniques, such as spectral nudging and precipitation assimilation as part of the physical initialization will also be applied and evaluated for each domain. In order to estimate the uncertainty using various global reanalyses for initialization model runs initialized with different analyses (e.g. European and Japanese) are being contemplated.

Results and Accomplishments
As part of the pilot phase of CEOP, Roads et al. (2003a) developed a preliminary comparison between the US National Centers for Environmental Prediction (NCEP) Seasonal Forecasting Model (SFM) being run at the Scripps Experimental Climate Prediction Center (ECPC) for CEOP, the US National Aeronautics and Space Administration (NASA) Data Assimilation Office (DAO) global model, and the NASA Global Land Data Assimilation System (GLDAS) land surface model with the Canadian Boreal Ecosystem Research and Monitoring Sites (BERMS) in situ observations (OBS). It was found sensible heating is largest in the GLDAS (GLD) and smallest in the SFM (ENP), in contrast to the latent heating. In comparison to latent heat released by precipitation, the sensible heating is quite small and the atmospheric balance is mainly between the radiative heating, latent heating, and heat convergence. The atmospheric radiative cooling is fairly constant, whereas the surface radiative heating shows a strong decrease from summer to fall. The subsurface heat flux is small but significant, especially in the SFM, and modulates the surface temperature by cooling the ground during the summer and heating it during the winter. The surface temperature was emulated best by the SFM. The diurnal variations were also examined. In the atmosphere, the heat convergence is positive during the day and negative during the evening hours, mainly because it is balancing the heating by diurnal precipitation and radiation processes. Surprisingly, perhaps, the atmospheric radiation cooling has a strong diurnal cycle and even becomes positive during the late afternoon. At the surface, solar radiation dominates during the day, and then long wave cooling becomes dominant during the evening. The heating by the subsurface heating is mostly positive during the evening and early

morning hours, and negative during the afternoon hours and is well emulated by the models. The largest discrepancy occurs in the surface fluxes, which are too large in most of the atmospheric models and too weak in the GLDAS, during the daytime.

Ruane et al. (2005) subsequently constructed a 3-month time series with a 3-hour interval from the 15-36 hour forecasts of each run. We then performed a least-squares fit to the diurnal and semidiurnal harmonics at each grid point, and average the amplitude and phase over a 3-year period. We have mapped the phase as color and the standard-deviation-normalized amplitude as intensity to represent the character of each diurnal cycle on a single plot. The Reanalysis II precipitation diurnal cycle displays many of the large-scale features observed, including a morning peak over the ocean and an afternoon peak over the continents. Observed regional characteristics are also well represented in summer analyses. These include a morning peak in precipitation over the southern Himalayas, a later peak over the mountainous portions of the United States than over the East, a nighttime maximum over portions of Argentina, large regions of low amplitude diurnal cycles off the tropical western coasts of continents, and fewer large-scale phase features over the oceans than over the land. Summertime diurnal cycles in surface temperature and evaporation appear to be driven by solar radiation, with afternoon peaks lagging local noon slightly. The diurnal cycle of winds shows a favoring of onshore and upslope flow during the day and offshore downslope flow at night. Peaks in water vapor convergence match many of the regional anomalies observed in the precipitation cycle, suggesting these regions' break from the radiation cycle is due to local dynamics.

Meinke et al (2005) are also evaluating the Regional Spectral Model (RSM) over seven different domains established as part of the ICTS (Rockel et al. 2005). For each domain two RSM runs have been carried out for July 1986 at 50 km horizontal resolution using NCEP reanalyses as initialization and boundary conditions. The only difference between these two model runs is the diagnostic cloud scheme. As the differences between model and data might not only be caused by model deficiencies, the ranges of uncertainties have to be estimated, first. This has been done for uncertainties caused by the model initialization and boundary conditions provided by the NCEP reanalysis and for the uncertainties caused by the ISCCP cloud detection algorithm. The ranges of uncertainty are estimated using the concept of a confidence band. The combined estimated range of these uncertainties is 12 %. Only if the differences between model and data exceed this uncertainty range, they can be identified as model deficiencies. The comparisons of the model runs and the ISCCP-D2 data indicate for all domains that the cloud cover derived by ISCCP is larger than the cloud cover simulated by both RSM runs. In some domains the difference of RSM and ISCCP does not exceed the estimated range of uncertainty of 12 % in others it does. This clarifies the uncertainty of a validation result based on one certain domain: The cloud parameterization may give good results for one domain. However, it may show deficiencies for another domain with different meteorological conditions. Transferring the model to the 7 different CSE domains gives a better insight on how often the differences between RSM and ISCCP exceed the uncertainty range. There are for both model runs more cases where the difference exceeds the uncertainty range than cases where the difference does not exceed the range of uncertainty. This indicates that both cloud schemes have a deficiency regarding the simulation of cloud

cover. Comparisons of the spatial distribution of clouds show that the two diagnostic cloud schemes used for the two different RSM runs have different strengths connected with different dynamical and physical processes. Sensitivity tests for both cloud schemes with decreased relative humidity thresholds show that best results can be achieved with decreased relative humidity thresholds in the Slingo scheme. After adjustment of the relative humidity threshold most of the differences between RSM and ISCCP do not exceed the range of uncertainty.

Future Work

We hope to further isolate strengths and weaknesses of our global and regional atmospheric models' handling of the diurnal cycle. Our models will most likely have the most trouble with areas dominated by synoptic and mesoscale weather patterns, as opposed to regions dominated by the planetary scale, where monthly means better represent diurnal patterns. That is, we expect differences in the models' ability to handle tropical versus higher latitudes, coastal versus inland areas, mountainous versus flat ground, and desert versus deciduous biomes. For each of these areas, the models' abilities to accurately reproduce a single variable may prove most important (for example land and sea breezes near coastal areas or solar insolation in the desert). Our model's performance may also shed light on the strengths and weaknesses of its convective (and other) parameterizations. Current models tend to overestimate the duration of precipitation events but underestimate their intensities, a result often overlooked in monthly averages. These errors also lead to inaccuracies on longer time scales. For example, lighter, steadier rain raises soil moisture more efficiently than a heavier, more rapid event, as less of the precipitated water becomes runoff. We are finding a strong geographical dependence in the diurnal cycle through analyses of observations and our model output.

Publications from this project

Meinke, J. Roads, M. Kanamitsu, 2005: RSM transferability studies during CEOP. Proceedings 85th AMS meeting. San Diego CA

Roads, J., M. Bosilovich, M. Kanamitsu, M. Rodell, 2003a: CEOP Pilot Data Comparisons. *CEOP Newsletter* March 2003a, Issue 3, pp. 2-5.

Roads, J., J. Marengo (co-chair), K. Szeto, D. Jacob, B. Rockel, T. Lebel, G. Takle, H. Berbery, M. Rodell, C. Peters Lidard, M. Bosilovich, K. Mitchell, 2003b: WESP Major Activities Plan.

Ruane, A., J. Roads, M. Kanamitsu, 2005: An examination of diurnal cycle characteristics in the experimental climate prediction center's global spectral models. Proceedings 85th AMS meeting. San Diego CA

Rockel, B., J. Roads, I. Meinke, W. Gutowski Jr., R. Arritt, E. Takle, 2005: ICTS (Inter-CSE Transferability Study): An Application of CEOP Data. Proceedings 85th AMS meeting. San Diego CA

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US and Global Water and Energy Budget Studies: A contribution to CEOP
Work plan: 03/01/2005 - 02/28/2006
Funding Request: $100,000

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1. Introduction

Our overall goal is to understand what components of the global water and energy cycles can be measured, simulated, and predicted at regional and global scales. In particular, we hope to isolate strengths and weaknesses of our and other atmospheric models' handling of the diurnal cycle. Models will most likely have the most trouble with areas dominated by synoptic and mesoscale weather patterns, as opposed to regions dominated by the planetary scale, where monthly means better represent diurnal patterns. That is, we expect differences in the models' ability to handle tropical versus higher latitudes, coastal versus inland areas, mountainous versus flat ground, and desert versus deciduous biomes. For each of these areas, the models' abilities to accurately reproduce a single variable may prove most important (for example land and sea breezes near coastal areas or solar insolation in the desert).

There are a number of diurnal cycles that can be analyzed in the data set. We are particularly interested in the separate diurnal cycles from the f00, f03, and f06 output as well as the f00-f24, f03-f27,…,f15-f36 daily forecast runs (initialized 12UTC). To analyze the diurnal characteristics of a particular variable, we will perform a least-squares fit to the diurnal harmonics at each grid point, and average the amplitude and phase over a 3-year period. We will also develop global patterns using EOF analysis. Our goal is to better understand the relationship of the precipitation variations to evaporation and

moisture convergence variations. In addition, we wish to understand better the diurnal variations in surface and atmospheric energetics. For example, what is the contribution to diurnal variations in latent heat release to diurnal variations in atmospheric radiative cooling and surface turbulent and large-scale vertical and horizontal heat convergence?

We have also developed preliminary global maps of a number of geophysical variables and believe the global models show promise in representing the diurnal cycle of precipitation, as well as revealing how different components of the water and energy cycles vary on diurnal scales. Additional model and seasonal comparisons could further explain what drives the diurnal cycle of precipitation in various regions and parameter schemes. We will also compare the model diurnal variations to observations in order to assess possible model deficiencies. For example, although these diurnal variations are similar to Nakamura (2003), we do note in particular the lack of a nocturnal maximum over the US Great Plains, even though the moisture convergence (not shown) is maximum during the nighttime. By contrast, the RSM simulations do have a nighttime maximum in precipitation and understanding why these differences occur between the global and regional models would be useful for developing more accurate global models.

2. Work Plan

- Finish submitting GSM Analysis and Forecasts and to MPI Archive for the period Jul. 1. 2001-Dec. 31, 2004
- Finish RSM Simulations over all 7 Regional areas for the period Jul. 1, 1999-2004
- Characterize Diurnal Variations in our Global and Regional Models and compare these results to in situ and remote sensing observations from CEOP archives

Budget Justification

The Joint Institute of Marine Observations requests funding in the amount of $100,000 in order to investigate/participate in the Office of Global Programs (OGP) GAPP Program. Dr. John Roads is the principal investigator (PI) of this project. He will be assisted by various personnel on the project. The additional personnel include a programmer/analyst and a graduate student researcher. The graduate student researcher will investigate CEOP variations and the staff research associate will provide diagnostic assistance.

Travel expenses are for presentations at scientific meetings and workshops (domestic and international). This project is data intensive and computer costs are needed to maintain the computer system for our work. Equipment is also used to connect to the computer network as well as provide the basic CEOP computations. Our system is built from commodity components and it is much more economical to purchase this type of equipment.

Project specific costs that include telephone equipment, tolls, voice and data communication charges, photocopying, faxing, postage, and laboratory supplies are requested. Supply and expense items, categorized as project specific, and computer and

networking services are for expenses that specifically benefit this project and are reasonable and necessary for the performance of this project.